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S.N.Vil'kova, I.A.Novikova, and D.Alavutdinov

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THE USE OF FOAMED POLYURETHANS FOR MANUFACTURING SOLAR ENERGY COLLECTORS

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S.N.Vil'kova, I.A.Novikova, and D.Alavutdinov

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A method for making solar energy collectors from rigid foamed polyurethans lined with mirror-like plastic films is described. Polyurethans used for this purpose were prepared from branched polyesters of dicarboxylic acids and triols or the combination of the latter with diols; the polyesters were combined with aromatic diisocyanates. Foamed polyisocyanates were obtained by combining a polyester resin prepared from glycerol (1.3 moles), sebacic acid (0.5 moles) and adipic acid (0.3 moles) with toluylene diisocyanate in a 10:7 ratio at room temperature; water was used to enhance foaming; the foam was stabilized with OP-7 or OP-10 emulsifier (0.3 - 0.5%). The foamed plastic obtained had good mechanical properties. Two types of solar energy collector were built: one-piece paraboloid collectors with a diameter of 280 or 410 mm, and facet collectors mounted from hexagonal facets with sides 55 mm long each. AUTHOR

As a result of their low specific weight, foamed polyurethanes afford the possibility of preparing light-weight solar energy collectors which can be readily carried from site to site as needed.

Gas-filled polyurethanes are derived from complex reactions, i.e., by

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* Numbers in the margin indicate pagination in the original foreign text.

mixing original components of polyester, diisocyanate, and water in the presence of suitable catalysts and emulsifiers.

The branched polyesters being used for the production of rigid foamed polyurethanes are obtained by esterification of dicarboxylic acids (adipic, sebacic, phthalic) with triols or a mixture of triols with diols. Of the diols, ethylene glycol and butanediol are useful. To obtain more stable foamed plastics, one ordinarily resorts to mixtures of acids (e.g., sebacic and adipic) in the proper ratios (Bibl.1).

For preparation of the polyester resin, we developed the following recipe: glycerol - 1.3 moles; sebacic acid - 0.5 mole; adipic acid - 0.3 mole.

The resin obtained was mixed with toluylene diisocyanate in a 10:7 ratio at room temperature.

Water was added to enhance the foaming, and the foam was stabilized with OP-7 or OP-10 emulsifier (0.3 - 0.5%).

The resultant foam was in the form of finely porous material, ranging in color from white to light yellow.

As is evident from Table 1, our foamed polyurethane is equal to the Vladimir foam in physico-mechanical properties, and is superior to it in strength.

The foamed polyurethane was used for making entire paraboloid solar energy collectors 280 and 410 mm in diameter, and individual hexagonal facets with sides 55 mm long for subsequent assembly of faceted collectors.

The whole collectors of foamed polyurethane were made as follows: A metal-plated polyethylene terephthalate film was placed in a round press consisting of a disk and a ring, which were seated to each other and connected by bolts. The film was inserted between the disk and the ring and was inflated to the necessary curvature by air injected through an orifice built into the ring. Thus we

obtained a mirror of metal-plated film, of a configuration close to paraboloid. For fixing and hardening the mirror, the film surface was coated with a thin layer of epoxy resin, which was held until completion of the polymerization process. The polymerized epoxy resin was then layered with the foam and /28 polymerized for 12 hrs at room temperature. After complete setting of the foam, the press was disassembled and the finished collector (Fig.1) withdrawn. The weight of such a collector with a diameter of 410 mm was 201 gm, whereas the weight of a collector of the same diameter made of epoxy resin with a filler was 930 - 1000 gm. The temperature of the receiver placed in the focal point of the collector was 880°C; the depth of arc (h) was 5 cm and the focal length (f), 21 cm.

TABLE 1

PHYSICO-MECHANICAL PROPERTIES OF FOAMED POLYURETHANE

Indexes	Unit of Measurement	Comparative Characteristics of Foamed Polyurethanes by Data Source	
		Physico-Technical Institute	VNIISSa*
Weight by volume	g/cm^3	0.085	0.045
Ultimate compressive strength, not less than	kg/cm^2	Samples do not break under effect of 100 kg/cm^2	2.0
Specific impact strength, not less than	$kg \cdot cm/cm^2$	1.15	0.4
Linear shrinkage at +120° for 24 hrs, max.	%	2	1.0
Water absorption for 24 hrs, max.	kg/cm^3	0.0006	1.0

* VNIISSa = Vladimir Scientific Research Institute of Synthetic Resins.

In the focal plane, the collector provides a spot with an area of S = = 1.54 cm^2 (size of the area was determined by photography).

To obtain hexagonal facets from the foamed polyurethane, we fabricated aluminum hexagonal molds with covers into which holes were drilled to release the air. Prior to pouring the foam into these molds, they were heated to 50°C. After the foam had been poured, the molds were placed in a thermostat and kept there for 1.5 hrs at 80 - 85°C. To avoid adhesion of the foam to the aluminum surface, the inner cavity of the aluminum mold was lined with a polyethylene film. On completion of the polymerization process, the molds were cooled for 12 - 15 hrs, after which the foamed polyurethane facet could be readily extracted. The weight of such a facet averaged 13.5 gm, at a length of a facet side of 55 mm.

The specular surface on such facets was obtained by applying thin epoxide coatings.

To produce a thin epoxide finish of 1 - 1.2 mm depth, epoxide resin was poured in a thin layer on the surface of aluminum spray-deposited onto plate glass and was left until completion of the polymerization process. Simultaneously with the polymerization, transfer of the deposited Al layer from the glass to the epoxide resin took place. In our case, the transfer was 100% effective, but removal of the thin resin layer from the plate glass proved impossible because of the strong adhesion of the resin to the glass. In the best case, the resin peeled off in small flakes.

During the work cycle, it was found that, if the deposited aluminum /29 coating was left undisturbed for a certain period (up to 45 hrs) prior to transfer, the process was accomplished much more easily. Obviously, during the holding period, the film of deposited aluminum sets up in some way, possibly

crystallizing. Thus, after having been held for 7 hrs, the epoxide resin begins to separate from the glass surface and transfers the aluminum to itself. After holding for 20 hrs, the resin can be completely removed, with the aid of a lancet, in the form of a thin film. After holding for 30 hrs, complete removal on light contact with the finish was obtained in 100% of all samples tested.

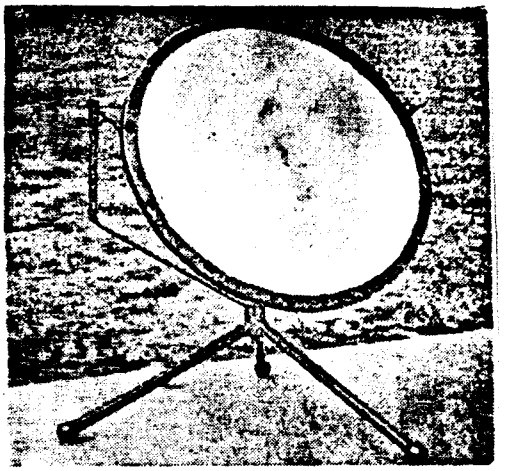

Fig.1 Paraboloid Solar Energy Collector Made of Foamed Polyurethane

To facilitate the process of transfer, we decided to study the effect - on a film of deposited aluminum - of ultrasonics, UHF currents, and elevated temperatures [the testing with ultrasound was dictated by the fact that ultrasound accelerates the aluminum crystallization process (Bibl.2)].

The work was conducted with a type UZG-2.5a ultrasonic generator of a power of 2.5 kw. At 1 cm^2, the rated power was 1 w/cm. The specimens (i.e., the aluminum deposits on the glass) were immersed in water at a temperature of 25°C for varying periods (from 1 to 3 min).

The ultrasonic treatment caused severe damage to the surface of the aluminum mirror; in some areas of the glass, the aluminum was completely removed. Although we assumed that the crystallization process had been accelerated, we

were unable to pinpoint this moment since the crystallization occurred instantaneously and the aluminum flew off the glass.

On exposing the aluminum mirrors to UHF currents for 10, 15, and 20 min at a power of 40 and 80 w, the transfer was facilitated considerably but severe shrinkage took place.

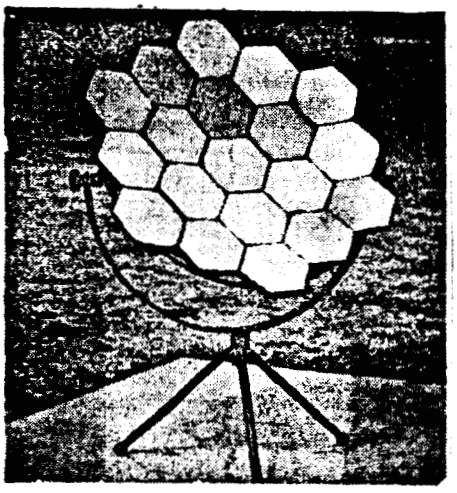

Fig.2 Faceted Collector Made of Foamed Polyurethane

For conducting the temperature tests, the aluminum surfaces were placed in a thermostat and held at 160 - 190°C for 2 - 2.5 hrs. After cooling, the surfaces were prepared for transfer, i.e., a thin resin coating was deposited on the surfaces and the specimen was placed in a thermostat heated to 55°C. After holding for 2 - 3 hrs at this temperature, the thin epoxide coating easily separated from the glass.

Thus only heating to high temperatures proved effective for easy removal of the thin epoxide films from a glass base.

The obtained thin epoxide specular surfaces were applied to hexagonal facets made of foamed polyurethane. From such facets, we assembled a mockup of a solar energy collector with a focal length (f) of 0.5 m (Fig.2). The model

consisted of 19 facets having a total surface area of 1444 cm^2.

The refractive index of an individual facet (η) was 0.9. In the focal /30 plane, the collector provides a spot with an area of 150 cm^2. Photography was used to determine the extent of the area. The temperature of the receiver installed in the focal point of the collector was 250°C.

The collectors made of foamed polyurethane passed all light and weathering tests during the hot summer months (June - July); Table 2.

TABLE 2

HEAT-ENGINEERING CHARACTERISTICS OF FOAMED POLYURETHANE COLLECTORS

Collector	Temperature in Focal Point, °C					
	Exposure, Days					Radiation, m^2kcal/hr
	0	15	30	45	60	
Paraboloid	925	925	880	880	820	630
Faceted	250	230	170	115	115	700

As is apparent from Table 2, the temperature of the receiver of the collector decreased by 135°C in two months. This was due to the fact that the surface of the transferred aluminum has no protection against mechanical damage and that, before each thermal test, the collector had to be washed clean of dust and dirt, which naturally caused removal of part of the aluminum during the washing process (we have not yet solved the problem of protecting the transferred surface).

The actual strength of the foamed polyurethane base did not vary under the effect of the sun; the base darkened slightly, changing from light- to dark-yellow.

We can thus state that we have developed a new technique for producing thin epoxide mirror-like finishes. We have shown the feasibility of using foamed polyurethanes for fabricating the body of solar energy collectors under conditions of the hot Central Asian summer.

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Physico-Technical Institute of
Uzbek SSR Academy of Sciences

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